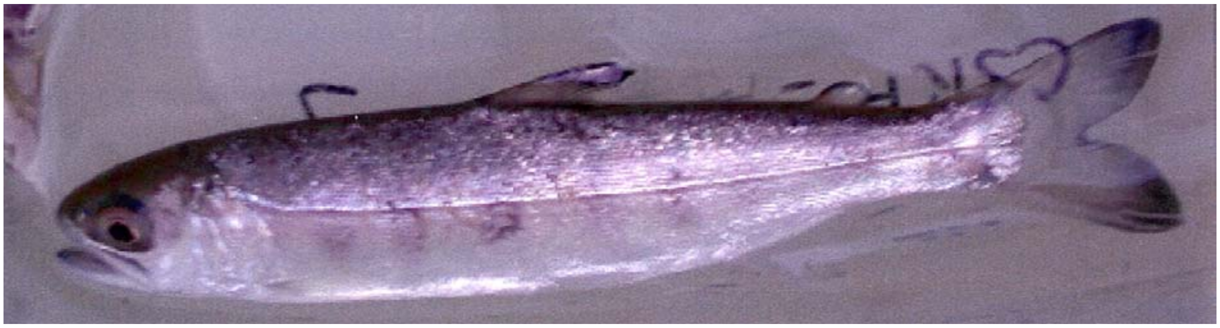
San Francisco Area Network
Inventory and Monitoring Program

National Park Service
US Department of the Interior

SPRING OUTMIGRANT SMOLT TRAPPING PROGRAM SUMMARY
OLEMA CREEK, PINE GULCH, AND REDWOOD CREEK WATERSHEDS, 2006



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Smolt Trapping Program Summary

OLEMA CREEK, PINE GULCH, AND REDWOOD CREEK, 2006

PORE/NR/WR/07-01

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ABSTRACT

The National Park Service has conducted multiple life stage monitoring of coho salmon in coastal Marin watersheds since 1998. Performed in conjunction with winter spawner surveys and summer juvenile surveys, the spring outmigrant surveys permit an evaluation of abundance and survival associated with the freshwater portion of their life-cycle. At the time they smolt, most coho have spent more than 14 months in the watershed, while steelhead can be 1-4 years old. Smolt production, therefore, is the best aggregate measure of watershed condition and productivity. When evaluated as part of a comprehensive monitoring program, the smolt trap information can be compared with adult spawner indices to describe potential ocean productivity and survival, and with summer juvenile population estimates to assess rates of survival through the winter season. Smolt trapping is conducted to obtain an estimate of total coho smolt production from three of the monitored watersheds: Olema Creek, Pine Gulch Creek, and Redwood Creek. The spring 2006 monitoring season was punctuated by late spring rains (3.5 inches at Bear Valley Headquarters between April 11-12) and high flow, which delayed trap installation until Julian week 16 (April 16-22). Conditions remained relatively dry and warm through mid-May, when the peak for outmigration was observed during Julian weeks 19 and 20 (May 7-20, 2006). This period correlated with cooler weather and some light rainfall. Redwood Creek estimates totaled 3,253 (±542). Capture efficiency ranged from 30% to 70%. In Olema Creek, capture efficiency ranged from 5% to 20%, resulting in a total coho smolt estimate of 10,544 (±8,399 s.d.). In Pine Gulch Creek, estimated capture efficiency ranged from 25% to 50% resulting in a total coho smolt estimate of 368 (±76 s.d.). A summary of egg to smolt survival for this reported year class indicates moderate conditions to support survival of coho in Olema (4.2%) and Pine Gulch Creek (5.6%), with Redwood Creek having the least rate of egg to smolt survival (1.5%). Development of these broader scale indices for survival in the watershed is key to effective habitat protection and management.

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1.0 BACKGROUND AND OBJECTIVES

Smolt trapping is performed in conjunction with winter spawner surveys and summer juvenile surveys. The spring outmigrant surveys provide a census of the number of smolts leaving a watershed and permit an evaluation of abundance during three of five distinct freshwater salmonid life history stages. When evaluated as part of a comprehensive monitoring program, the smolt trap information can be compared with adult spawner indices to describe potential ocean productivity and survival, and with summer juvenile population estimates to assess rates of survival through the winter season. This type of comprehensive monitoring information is rare in this region, as most of this research has been focused in the Pacific Northwest.

The outmigrant program is conducted in selected salmonid-bearing watersheds where the NPS is performing basinwide population estimates. The program requires intensive monitoring at specific locations for a period of two to three months during the spring of each year. This report documents results of the Spring 2006 trapping season at Olema Creek, Pine Gulch Creek and Redwood Creek.

1.1 Introduction and History of Spring Outmigrant Smolt Trap Program

A significant body of literature has documented life-stage bottlenecks and survival rates for salmonid populations. Many of these studies describe how alterations to watershed connectivity and condition affect these species at these different freshwater life stages. At the time they smolt, coho have spent more than 14 months in the watershed, while steelhead can be 1-4 years old. Smolt production, therefore, is the best aggregate measure of watershed condition and productivity. The response of coho and steelhead populations to changes in habitat quality can not be properly assessed without a measure of smolt production.

The habitat and climate supporting salmonids in this central California coast area have not been well studied, meaning that local adaptations by these species are not well documented. Smolt trap monitoring, in conjunction with other life stage monitoring activities allows the NPS to characterize aggregate watershed productivity for salmonids, and is a valuable resource for directing long-term management and restoration actions. Data collected through smolt trapping also has direct management utility. Trapping results can also help quantify dates of fry emergence and growth rates through the spring season. Outmigrant traps also provide presence/absence information and size data for other aquatic species during periods not covered by summer/fall monitoring activities.

The NPS conducted smolt trapping operations at selected sites since 1998. Between 1998 and 2004, the NPS conducted outmigrant trapping on the John West Fork, an important tributary of Olema Creek, immediately upstream of the State Route 1 culvert. The results of these efforts showed increases in watershed productivity in response to fish passage restoration efforts in summer 1999. In addition to the John West Fork trap, the NPS operated four other traps in 1999 that showed the importance of tributaries to overall watershed smolt production.

In 2002 the NPS initiated smolt trapping on Pine Gulch Creek to monitor the size and condition of the coho population that had recently re-colonized this watershed. In order to obtain an estimate of total coho smolt production from the Olema Creek watershed the NPS initiated trapping at the downstream end of Olema Creek in 2004. In 2005 smolt trapping operations were expanded to include Redwood Creek.

Spring Outmigrant Trapping Monitoring Objectives

1. Determine health condition factor of salmonid smolts within Olema, Redwood, and Pine Gulch Creeks.
2. Estimate the annual production of coho smolts within Olema, Redwood, and Pine Gulch Creeks using spring outmigration trapping.

Spring Outmigrant Trapping Monitoring questions

1. How does coho and steelhead condition factors compare between small coastal drainages in PORE/GOGA watersheds, Central California Coast ESU, and the northern California-southern Oregon ESU?
2. What is the time of peak outmigration in Olema, Redwood, and Pine Gulch Creeks?

1.1.1 Other Monitoring Programs
In 2006, downstream migrant trapping operations were initiated on Lagunitas Creek as part of a Limiting Factors Analysis grant through the Marin Resource Conservation District. The trapping conducted in 2006 by Stillwater Sciences, Inc. may be duplicated in future years by Marin Municipal Water District (MMWD). In addition, the Salmon Protection and Watershed Network (SPAWN) initiated smolt trapping on San Geronimo Creek in 2006, with plans and permits to continue this work into future years. With respect to coho salmon, information from all three programs will fill an important information gap linking summer juvenile density to adult returns one or two winters later.

1.2 Fish Resources
The primary species monitored through this program are coho salmon and steelhead trout. However, other aquatic species including sculpin, roach, lamprey, and stickleback are captured and documented through our monitoring efforts.

1.2.1 Coho Salmon

Biology

The general biology of coho salmon is described in detail in Hassler (1987) and Sandercock (1991). The coho salmon is an anadromous, semelparous fish species, migrating from marine water back to freshwater for a single chance at reproduction. Coho generally return to natal streams after spending two years in the ocean. The spawning migrations begin after heavy late-fall or winter rains breach the sandbars at the mouth of coastal streams allowing the fish to move upstream. Spawning occurs in small to medium sized gravel at aerated sites, typically near the head of a riffle (Moyle 1976). These streams have summer temperatures seldom exceeding 21 degrees Centigrade (70 degrees Fahrenheit). Emergent fry use shallow near-shore areas, whereas optimal habitat conditions for juveniles and sub-adults are deep pools associated with rootwads, woody debris, and boulders in shaded stream sections (Laufle et al 1986). The distribution and habitat of coho juveniles partially overlaps with that of the California red-legged frog.

Because of dramatic declines in population numbers, the National Marine Fisheries Service (NMFS) was petitioned to list this species coastwide (Federal Register 1996). Several runs were listed along the central California coast and include regions occupied by California red-legged frogs. Causes of coho salmon declines in California include incompatible landuse practices such as logging and urbanization, loss of wild stocks, introduced diseases, over harvesting, and climactic changes.

Coho salmon are known to exist in watersheds including Lagunitas, Olema, Pine Gulch (Brown and Ketcham 2002), and Redwood Creeks. Walker Creek, which flows into Tomales Bay, likely supported coho salmon and is part of a larger coho recovery program conducted by the California Department of Fish and Game and NOAA-Fisheries.

Regulatory Protection

NOAA-Fisheries

Coho salmon were listed as a threatened species within the central California coast coho salmon ESU (CCCESU) on October 31, 1996 by the National Marine Fisheries Service (NOAA-Fisheries) (Federal Register 1996). The CCCESU (Figure 1.1) includes all naturally spawned populations of coho salmon from Punta Gorda in northern California south to and including the San Lorenzo River in central California, as well as populations in tributaries to San Francisco Bay, excluding the Sacramento-San Joaquin River system. The original listing criteria stated that the Lagunitas/Olema Creek population accounted for more than 10% of the wild coho population (Brown et al 1994) in the CCCESU. Recent research through the NPS, Marin Municipal Water District (MMWD), and Salmon Protection and Watershed Network (SPAWN) have shown that the Lagunitas population likely represents more than 20% of the CCCESU population.

In association with the coho threatened listing NOAA-Fisheries designated critical habitat for coho salmon on May 5, 1999 (Federal Register 1999). The critical habitat is designated to include all river reaches accessible to listed coho salmon from Punta Gorda in northern California south to the San Lorenzo River in central California, including Mill Valley (Arroyo Corte Madera Del Presidio) and Corte Madera Creeks, tributaries to San Francisco Bay. Excluded are areas above specific dams or above longstanding, naturally impassable barriers (i.e., natural waterfalls in existence for at least several hundred years). Major river basins containing spawning and rearing habitat for this ESU comprise approximately 4,152 square miles in California. The following counties lie partially or wholly within these basins: Lake, Marin, Mendocino, San Mateo, Santa Clara, Santa Cruz, and Sonoma.

In their 2001 Status Review, NOAA-Fisheries acknowledged that within the CCCESU, the decision to list coho salmon as threatened may have been overly optimistic, concluding that the ESU population was presently endanger of extinction (NMFS 2001). As a result of these and further findings, NOAA-Fisheries completed a rulemaking process in June 28, 2005, which downgraded the coho status (upgraded listing protection) in the ESU to Endangered (Federal Register 2005).

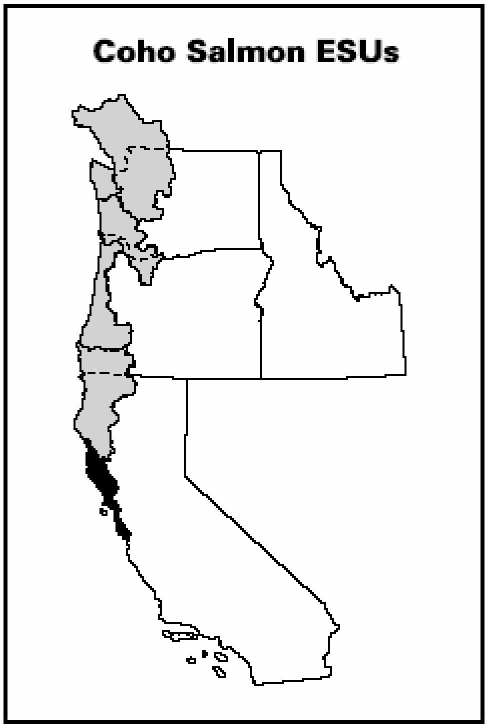
California Department of Fish and Game
On April 5, 2001, the Fish and Game Commission accepted the petition to list coho salmon north of the Golden Gate as endangered under the State Endangered Species Act. As a response to this petition, the DFG prepared a status review of California which concluded that the coho salmon within the central California coast ESU (as designated by NOAA Fisheries – Figure 1.1) are in serious danger of becoming extinct throughout all or a significant portion of its range, and that the endangered listing is warranted (CDFG 2002). As a response, the CDFG released a draft Recovery Strategy for coho salmon in November 2003, which was adopted as revised by the Fish and Game Commission on February 6, 2004. On August 5, 2004, the Fish and Game Commission added coho salmon populations between San Francisco and Punta Gorda to the list of species protected under the Endangered Species Act (areas south of San Francisco were already listed as endangered). This listing became effective March 30, 2005.

1.2.2 Steelhead

Biology
Steelhead are the anadromous form of rainbow trout; adult steelhead typically spawn in gravel riffles in the spring, from February to June. Steelhead are multiparous, meaning they can spawn more than once. Research conducted in the 1950s documented female steelhead returning to spawn in multiple years (Shapavolov and Taft 1954). Optimum temperatures for growth range from 13 to 21 degrees Centigrade (55 to 70 degrees Fahrenheit) (Moyle 1976). It is also noted that steelhead may persist in a broad range of pH (from 5.8 to 9.6) but prefer a pH between 7 and 8 (Moyle 1976). Steelhead fry reside in near-shore areas. Steelhead juveniles tend to use riffles and pool margins. Because of dramatic declines in population numbers, the National Marine Fisheries Service (NMFS) was petitioned to list this species throughout much of the California coast.

Steelhead trout are known to exist in most perennial watersheds within Marin County.

Regulatory Protection
Steelhead were listed as a threatened species on August 17, 1997 (Federal Register 1997). As of February 6, 2006 the former steelhead Evolutionary Significant Unit has been changed to a Distinct Population Segment (DPS). The central California coast steelhead DPS includes all naturally spawned populations of steelhead (and their progeny) in California streams from the Russian River (inclusive) to Aptos Creek (inclusive), and the drainages of San Francisco, San Pablo, and Suisun Bays eastward to Chipps Island at the confluence of the Sacramento and San Joaquin Rivers; excluding the Sacramento-San Joaquin River Basin. The artificially propagated stocks from the Don Clausen Fish Hatchery and the Kingfisher Flat Hatchery/Scott Creek are also included (Federal Register 2006). As of the 2006 Federal Register, only ocean-run *O. mykiss* (steelhead trout, not resident rainbow trout) are protected under the ESA. In 2000, critical habitat was designated for steelhead along the California coast. In 2002 these designations were withdrawn due to a National Marine Fisheries Service (NMFS) decree and weren't reinstated until a final ruling in August 2005. This critical habitat became effective January 2, 2006 (Federal Register 2006). Critical habitat only encompasses the *O. mykiss* anadromous range.



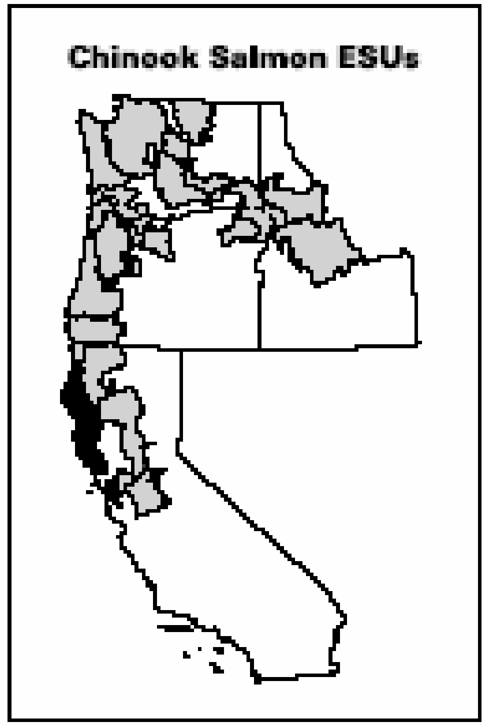


Figure 1.1 Coho salmon Evolutionarily Significant Units and Chinook salmon Evolutionarily Significant Units as identified by NOAA Fisheries. Marin County is included within the Central California Coast ESU for coho salmon (left).

1.2.3 Chinook Salmon

California Coastal Chinook salmon were listed as threatened on September 16, 1999; threatened status reaffirmed on June 28, 2005. The ESU includes all naturally spawned populations of Chinook salmon from rivers and streams south of the Klamath River to the Russian River, California (Figure 1.1). Though not included in the listed area, adult Chinook salmon have been observed within Lagunitas Creek in increasing numbers since 2000 (MMWD 2006). The increasing frequency of Chinook salmon within Lagunitas Creek may indicate the development of a self-sustaining population, but whether this will persist is unclear (NOAA Fisheries 2004). Because of the proximity of these fish to the southern boundary of the ESU, NOAA Fisheries has treated this watershed population as part of the California Coastal listed population for the purposes of other consultations on the lands of Point Reyes National Seashore and Golden Gate National Recreation Area (NOAA Fisheries 2004).

1.2.4 Essential Fish Habitat

The Magnuson-Stevens Fishery Conservation and Management Act, as amended by the Sustainable Fisheries Act of 1996 (Public Law 104-267) requires all Federal agencies to consult with NMFS on all actions, or proposed actions, permitted, funded, or undertaken by the agency, that may adversely affect Essential Fish Habitat (EFH). EFH is defined as "those waters and substrate necessary to fish for spawning, breeding, feeding, or growth to maturity." “Waters” include aquatic areas and their associated physical, chemical and biological properties. “Substrate” includes sediment underlying the waters. “Necessary” means the habitat required to support a sustainable fishery and the managed species' contribution to a healthy ecosystem. Spawning, breeding, feeding, or growth to maturity covers all habitat types utilized by a species throughout its life cycle. NMFS would provide recommendations to conserve EFH to Federal or state agencies for activities that would adversely affect EFH.

1.2.5 Historical Fishery Resources

Review of the historical background information shows that fisheries resources have declined dramatically since the turn of the century. As early as 1892, reports of declines in fish abundance within the streams of western Marin County were circulated. Interviews with long time residents and former as well as present fisheries resource managers support the contention that fisheries resources within the area have been declining for years and that the most significant and noticeable changes have occurred since the mid-1950's. It is well established that both the abundance and distribution of coho salmon and steelhead trout has declined throughout the area. Interestingly, though most of the changes in fish populations have occurred within the past 50 years, the majority of the most exploitive land use practices (dairy and logging) ended more than seventy years ago.

There is little doubt that historic exploitation of the forest, grassland, and fisheries associated with western Marin County has severely impacted the extent of existing coho salmon and steelhead trout populations.

2.0 METHODS

2.1 Pipe and Fyke Trap Construction

The trapping is conducted continually for a 2-3 month period during the spring and requires daily checking by field staff. The pipe traps used by this program are based on methods developed in northern California for trapping small streams (Manning and Roelofs 1996; Manning 2001) and have proven effective for the current monitoring sites. They are designed to catch fish moving downstream and effectively result in a census of smolt outmigration. Trap sites were determined by location within each watershed, suitable channel morphology, and access (Figure 2.1).

On Pine Gulch Creek a pipe trap operates by impounding water behind a weir constructed of ½ inch mesh hardware cloth and t-posts that spans the entire width of the stream. Flow is directed into a series of 20 ft. long, 8 inch diameter PVC pipes. To decrease water velocity, the pipes empty onto a slanted, perforated metal ramp (McBain's ramp). The ramp is connected to a 125 x 74 x 50 cm box constructed of plywood and 1/8 inch mesh hardware cloth. The trap box contains a baffle to further slow water velocity, as well as a mesh divider screen to provide cover and refugia for fry. A bypass channel is provided on one side of the weir to allow adult steelhead to migrate upstream during higher flows.

The fyke/pipe trap on the Olema and Redwood Creeks is based on a design used by CDFG on the Noyo River (Gallagher 2000; Barrineau and Gallagher 2001). A 5' x 20' fyke net is supported by t-posts and a frame consisting of 1" galvanized pipe. Several weir panels are constructed consisting of ½" mesh hardware cloth secured with t-posts and zip ties to direct fish into the mouth of the fyke net. A small gap is left between the weir panels and the streambank on one side to allow upmigrating steelhead to pass. The throat of the fyke net is attached to a series of 6" x 20' PVC pipes, which empty into a plywood trap box as described above.

Traps are generally installed in mid-March, once winter flows have subsided and stabilized somewhat. In some years, spring rains occasionally raise flows enough to compromise trap operation. Stream flows usually drop substantially by late May or early June, so traps are usually removed at this time. A Hobo-brand temperature logger is deployed and left in each trap box for the duration of operation.

Figure 2.1 Location of smolt traps on SFAN streams in Marin County, CA.

2.2 Mark/Recapture techniques

Mark-recapture methods are used to estimate trap efficiency and smolt population size using other trap designs that trap only a part of the water column. Daily, no more than 30 smolts (or 50% of the catch that day) of each species (coho and steelhead) are anesthetized with carbon dioxide and marked with small but identifiable fin clips, or dye on fins using a needleless injector. Marked smolts are released immediately at a predetermined site no more than 200 meters above the trap site. Mark combinations are alternated weekly. All adults, parr, fry, and recaptured smolts are released immediately after measurement in low velocity areas below the trap.

Studies using similar methods have demonstrated little marking mortality and no fish are held for retention or survival tests (Thedinga et al. 1994). A study using the same methodology on five northwestern California streams revealed that trap mortality was less than one percent for smolts and less than three percent for fry (Manning 2001). The highest mortality rates were associated with high flow.

Mark/recaptured data is analyzed using DARR (Darroch Analysis with Rank Reduction), a software application developed by Eric Bjorkstedt at the NMFS Southwest Fisheries Science Center (Bjorkstedt 2000). The software facilitates analysis of temporally stratified mark/recapture data based on methods developed by Darroch (1961).

Using the efficiency method to estimate population could result in overestimates of population. Estimates reported through this method require the following assumptions: 1) there is no mortality of released fish; 2) there is no residualization or behavior change (far more probable in steelhead than coho); and 3) released fish are redistributed and have a constant probability of capture.

2.3 Processing 1+ aged Fish

Daily, a random sub-sample of steelhead parr, coho and steelhead presmolts, coho and steelhead smolts, and steelhead residents are measured and weighed. This sub-sample is normally 10 of each species, however, if fish are anesthetized for mark-recapture purposes, they are also measured. All steelhead parr, coho and steelhead presmolts, coho and steelhead smolts, and steelhead residents are identified and counted. Any adult steelhead encountered in the trap is released downstream immediately.

Selected age 1+ salmonids are sedated using carbon dioxide to facilitate handling and minimize stress to the fish. A clean five-gallon bucket is filled with a couple inches of fresh stream water and then half of an Alka-Seltzer® tablet is added (plain, unmedicated). The alka-seltzer adds carbon dioxide to the water, effectively slowing the fish down and sedating them. No more than two fish at a time are placed into the treated water. Fish are determined to be adequately sedated when they are sluggish enough for easy handling but before they begin to turn over. The water is changed periodically, particularly on hot days and when processing large numbers of fish.

Salmonids are identified to species and life stage (fry, parr, presmolt, smolt, resident, or adult), measured (fork length is measured nose to fork of caudal fin) to the nearest millimeter (mm), and weighed to the nearest 0.01gram (g) using an electronic scale. Non-salmonid fish and other aquatic species are also identified, aged if possible, measured, and weighed. Age 1+ steelhead and coho are separated into the following morphological categories: smolt (faint or absent parr marks, silver body, deciduous scales, black fin margins), parr (smaller size, parr marks present), and pre-smolt (intermediate characteristics) (Bratovich and Kelley, 1988; Nelson 1994). Occasional runback steelhead spawners are trapped on their way back out to sea; they are generally >40 cm long and are classified as adults. Steelhead which are smolt-sized or larger with no smolt characteristics, and which exhibit rainbow trout characteristics are classified as residents. Any mortality or injury is recorded, as well as the probable cause of death.

In general, coho measuring more than 70 mm in the spring are assumed to be one year old and potential smolts. It is the judgment of the field staff to determine whether the fish is a smolt or presmolt. Typically, coho entering the trap are actively migrating downstream. Smolts undergo physical change in their body, becoming silvery, and developing black tips on their caudal fin (this is true of both coho and steelhead). Smolts also have looser scales, and are losing their parr marks and spots. While descriptions can be made, the judgment between smolt and presmolt is truly based on appearance of the fish and determination in the field.

Tissue samples are collected on all steelhead and coho mortalities for genetic analysis by the NOAA - Fisheries Genetics Lab in Santa Cruz, California. Sample collection follows NOAA - Fisheries protocol and is performed as part of the Section 10 permit 1046.

2.4 Processing Young of Year Salmonids

All fry are identified to species and counted. Daily, random sub-samples of 10 coho fry and 10 steelhead fry are measured (fork length to the nearest mm) and individuals greater than 40 mm are weighed to the nearest 0.01 g using an electronic scale. Sub-samples are obtained by taking blind scoops out of the holding bucket with a small aquarium dip net.

Although identification of salmonid fry can be difficult, it is important that the species (coho and steelhead) are differentiated. As long as both species are present, it is rather simple to see the distinct differences. Problems may arise when only one or the other is present. The best reference for field identification between species is the "Field Identification of Coastal Juvenile Salmonids" (Pollard et. al 1997). This reference includes color photographs and descriptions of each species at the 40 to 50 mm size. In general, the coho at all sizes have a pinker hue, while steelhead have an orange or yellow hue. In addition, the dorsal and anal fins of coho are longer, sickle-shaped, and more pointed than those of steelhead. For the few individuals that can't be identified by overall appearance or shape of fins, counting the anal fin rays can differentiate between coho and steelhead fry.

2.5 Processing Other Species

Other species encountered through this program are documented. Daily, random sub-samples of 10 individuals of each species are measured and fish over 40 mm are weighed. All other species are counted and released downstream.

We have observed that sculpin, as ambush predators, will take smolt sized fish in the trap. Comparing weight-length relationships of sculpin taken from the trap allows us to document how many sculpin may have taken fish. This technique has also been used to evaluate whether 1+ aged steelhead have taken young of year while in the trap. Where sculpin are typically present (in all downstream traps), we have removed cover to reduce their ability to hide and ambush other fish. In addition, once removed from the trap, sculpin are held in a separate bucket to avoid predation.

2.6 Fish recovery and release

After processing, each fish is placed in an aerated recovery bucket, keeping larger sculpin in separate buckets to avoid predation on smaller fish. The recovery bucket is a different color (preferably blue or other dark color) or located away from the holding buckets to avoid mixing fish that have and haven't been processed. The dark colored bucket allows the fish to darken their color, which is beneficial when they are released back to the pools. Fish in the recovery bucket are monitored to insure sedated fish recover fully before being released.

3.0 RESULTS

Results for smolt trapping are reported by Julian week to support analysis across year and watershed. The terminology used in this section refers to the trapping season extending from Week 15 (April 9-15) through Week 23 (June 4-10). Typically trapping would be initiated by Week 12 (March 19-25).

3.1 Redwood Creek

During the 2006 outmigrant trapping study, the Redwood Creek trap was in place for 53 days (from April 18 through June 9) and was fully operational for 49 days. Trap installation was delayed until mid April due to high flows caused by several large storm events. Ideally trap installation would occur in early to mid March to encompass the entire smolt outmigration period.

The trap captured a total of 1043 coho smolts and five coho presmolts. The trap captured a total of 10 steelhead smolts and seven steelhead presmolts. The mortality rate for 1+ coho was 0.8% (8/1043). The mortality rate for 1+ steelhead was 11.8% (2/17). The higher mortality rate for 1+ steelhead was is partly a function of the much smaller sample size. The recapture rate for marked coho smolts was 42.6% (281/660) and 18.2% (2/11) for marked steelhead 1+. Peak capture for coho smolt/presmolts occurred during the first two weeks of May (Figure 3.4). A second peak capture for coho smolt/presmolt occurred at the end of May and beginning of June (Figure 3.4). DARR analysis of the coho smolt data stratified by week (Figure 3.1) showed the estimated capture probability at around 15% for the first three weeks of trap operation, then increasing in week six to around 50%, resulting in a total coho smolt estimate of 3,253 (±542). Capture efficiency was variable in weeks four and five with estimated efficiencies ranging from 30% to 70%.

Also captured during this season were 51 fry, of which 27 (53%) were coho and 24 (47%) were steelhead. The coho YOY mortality rate for the duration of trap operation was 3.7% (1/27) and the steelhead YOY mortality rate was 4.1% (1/24). Peak capture of outmigrating coho occurred in Weeks 18 and 19, with nearly half the seasonal total observed at that time. Steelhead fry capture peaked in early May (Week 18), and coho fry capture peaked in mid April just as the trap installation was completed (Weeks 16 and 17).

Table 3.1 Redwood Creek Smolt Trap Summary, April 18 – June 9, 2006

Julian			Steelhead						Coho		
			Juvenile				adult				
Week #	From	To	smolt	presmolt	parr	fry	res	spawner	smolt	presmolt	fry
Week 15	9-Apr	15-Apr	n	n	n	n	n	n	n	n	n
Week 16	16-Apr	22-Apr	1	2	0	8	0	0	0	1	25
Week 17	23-Apr	29-Apr	7	0	0	1	0	0	45	1	2
Week 18	30-Apr	6-May	2	0	0	13	0	0	230	3	0
Week 19	7-May	13-May	0	3	0	1	0	0	274	0	0
Week 20	14-May	20-May	0	0	0	0	0	0	143	0	0
Week 21	21-May	27-May	0	0	0	1	0	0	142	0	0
Week 22	28-May	3-Jun	1	1	0	0	0	0	170	0	0
Week 23	4-Jun	10-Jun	0	1	0	0	0	0	39	0	0
		TOTALS	**11**	**7**	**0**	**24**	**0**	**0**	**1043**	**5**	**27**

Totals include mortalities.
n= trap not installed

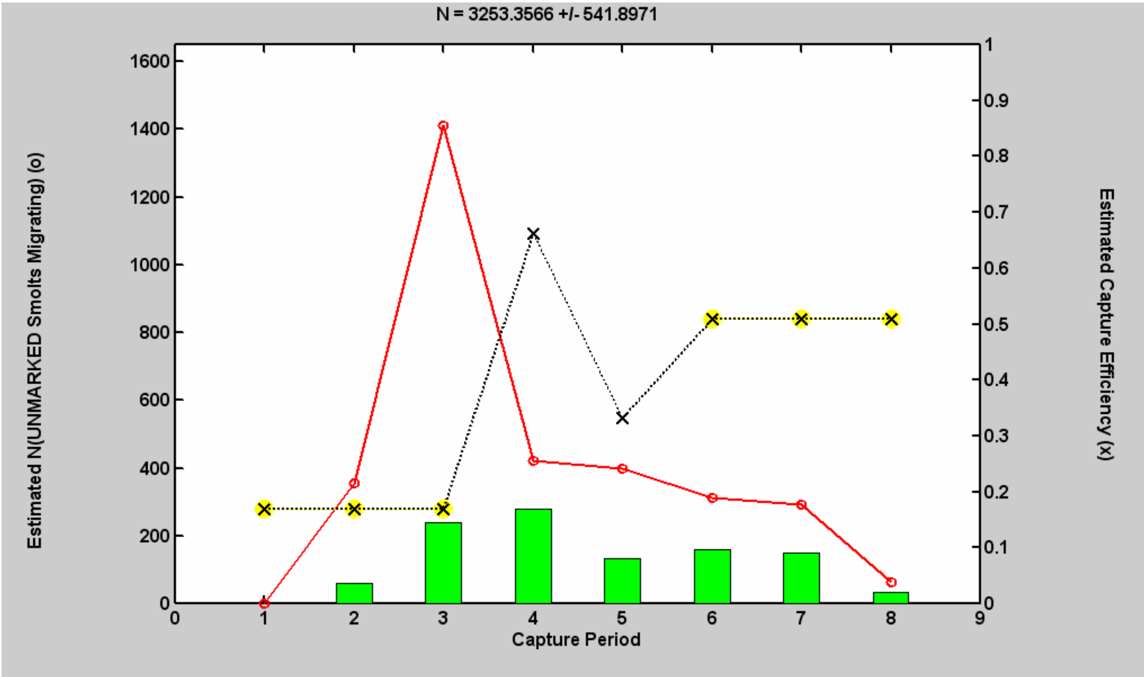


Figure 3.1 Darr analysis of smolt data stratified by week for Redwood Creek, 2006.

3.2 Olema Creek

During the 2006 outmigrant trapping study, the Olema Creek trap was in place for 54 days (from April 10 through June 9) and was fully operational for 45 days. Trap installation was delayed until mid April due to high flows caused by several large storm events. Ideally trap installation would occur in early March to encompass the entire smolt outmigration period.

The trap captured a total of 364 coho smolts and four coho presmolts. The trap captured a total of three 1+ steelhead smolts, three 1+ steelhead presmolts and 19 steelhead 1+ parr. The mortality rate for 1+ coho was 1.9% (7/368). There were no 1+ steelhead mortalities. The overall recapture rate for 1+ coho was 11.2% (26/233). DARR analysis of the coho smolt data stratified by week (Figure 3.2) showed the estimated capture probability at less than 5% for the first four weeks then increasing to 20% in week 5 but then dropping down to 10% during the final three weeks, resulting in a total coho smolt estimate of 10,544 (±8,399 s.d.). No steelhead 1+ were recaptured although three were marked and released above the trap. Peak capture for coho smolts/presmolts occurred in mid May, during week 20 (Figure 3.4).

Also captured during this season were 548 fry, of which 51 (9%) were coho and 497 (91%) were steelhead. Both steelhead and coho fry capture peaked in late April (Week 17). The coho YOY mortality rate for the duration of trap operation was 9.8% (5/51) and the steelhead YOY mortality rate was 8.5% (42/497).

The results of trapping Olema Creek are indicative of a less than ideal trapping location. Staff will evaluate lower Olema Creek for a better trapping location, to improve efficiency and ultimately monitoring results (See Section 5.1).

Table 3.2 Olema Creek Smolt Trap Summary, April 10 –June 9, 2006

Julian			Steelhead						Coho		
			juvenile				adult				
Week #	From	To	smolt	presmolt	parr	fry	res	spawner	smolt	presmolt	fry
Week 15	9-Apr	15-Apr	0	0	0	9	0	0	0	0	0
Week 16	16-Apr	22-Apr	0	0	5	17	0	0	1	0	1
Week 17	23-Apr	29-Apr	3	0	7	193	0	0	15	3	44
Week 18	30-Apr	6-May	0	0	0	131	0	0	25	0	5
Week 19	7-May	13-May	0	0	0	90	0	0	53	0	0
Week 20	14-May	20-May	0	0	4	6	0	0	107	1	0
Week 21	21-May	27-May	0	0	3	16	0	0	70	0	1
Week 22	28-May	3-Jun	0	3	0	21	0	0	49	0	0
Week 23	4-Jun	10-Jun	0	0	0	14	0	0	44	0	0
		TOTALS	**3**	**3**	**19**	**497**	**0**	**0**	**364**	**4**	**51**

Totals include mortalities.

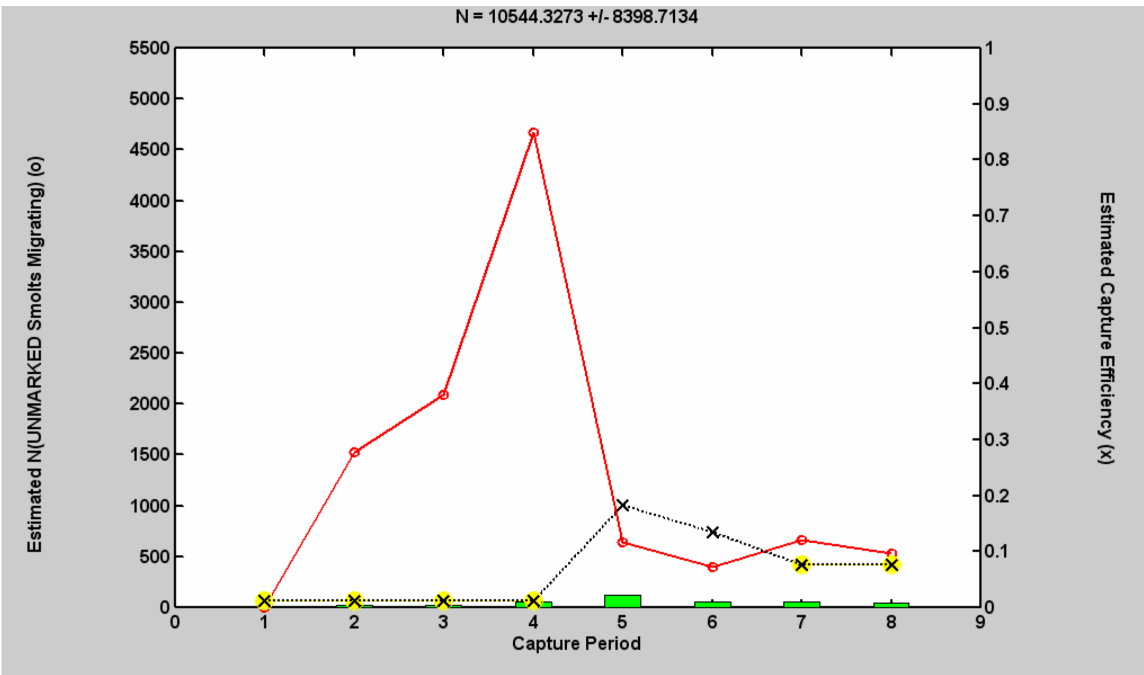


Figure 3.2 Darr analysis of smolt data stratified by week for Olema Creek, 2006.

3.3 Pine Gulch Creek

During the 2006 outmigrant trapping study, the Pine Gulch trap was in place for 45 days (from April 26 through June 9) and was fully operational for 43 days. During the entire trapping season a considerable amount of flow was allowed to pass down a side channel that was adjacent to the trap. Sandbags and erosion cloth were placed at the head of the side channel to decrease the likelihood of fish immigrating down the side channel instead of the main channel. Trap installation was delayed until mid April due to high flows caused by several large storm events. Ideally trap installation would occur in early March to encompass the entire smolt outmigration period.

The trap captured a total of 93 coho smolts and 18 steelhead 1+, including two smolts, nine presmolts, and seven parr. There were no 1+ coho or steelhead mortalities observed. The overall recapture rate for marked steelhead 1+ was 25.0% (1/4) and 25.6% (22/86) for coho 1+. DARR analysis of the coho smolt data stratified by week (Figure

3.3) showed the estimated capture probability at nearly 25% for the first four weeks then dropping slightly in Week 5 before increasing to nearly 50% for the final three weeks of the trapping operation. The estimated capture efficiency resulted in a total coho smolt estimate of 368 (±76 s.d.). Peak capture of coho smolts/presmolts occurred mid May during Week 19 (Figure 3.4).

Also captured during this season were two steelhead fry and one coho fry. No steelhead or coho fry mortalities were observed.

Table 3.3 Pine Gulch Creek Smolt Trap Summary, April 26 - June 9, 2005

Julian			Steelhead						Coho		
			juvenile				adult				
Week #	From	To	smolt	presmolt	parr	fry	res	spawner	smolt	presmolt	fry
Week 15	9-Apr	15-Apr	n	n	n	n	n	n	n	n	n
Week 16	16-Apr	22-Apr	n	n	n	n	n	n	n	n	n
Week 17	23-Apr	29-Apr	1	0	0	0	0	0	7	0	0
Week 18	30-Apr	6-May	1	0	0	0	0	0	5	0	1
Week 19	7-May	13-May	0	2	1	1	0	0	43	0	0
Week 20	14-May	20-May	0	2	0	0	0	0	21	0	0
Week 21	21-May	27-May	0	0	2	1	0	0	7	0	0
Week 22	28-May	3-Jun	0	2	1	0	0	0	5	0	0
Week 23	4-Jun	10-Jun	0	3	3	0	0	0	5	0	0
		TOTALS	**2**	**9**	**7**	**2**	**0**	**0**	**93**	**0**	**1**

Totals include mortalities.
n= trap not installed

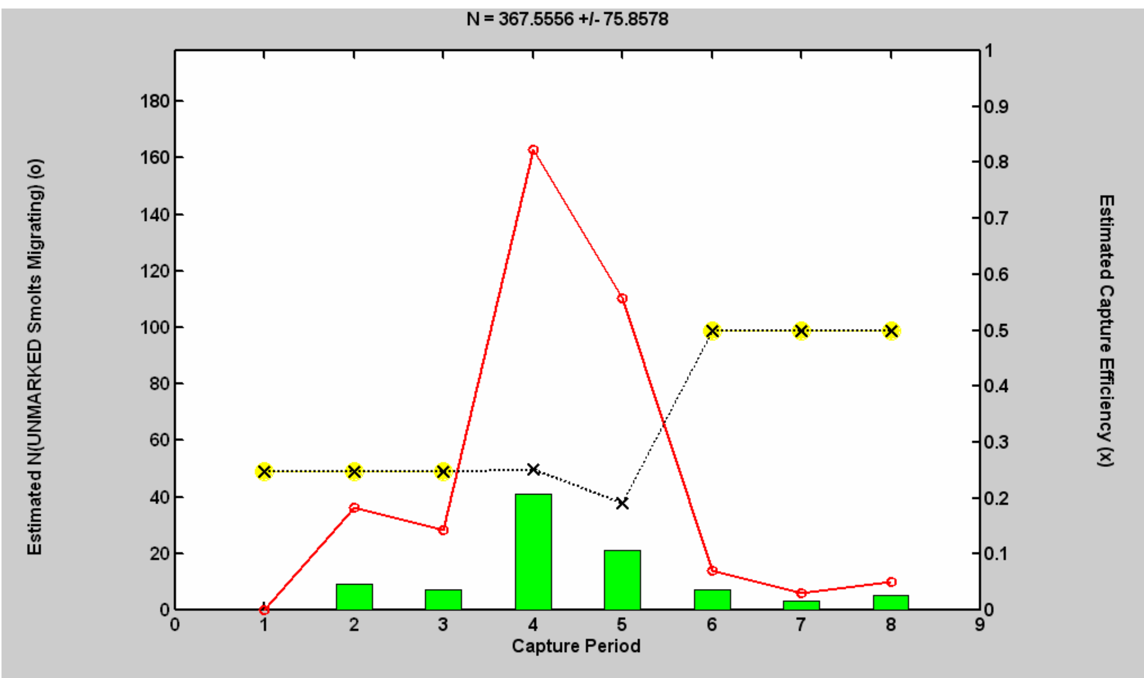


Figure 3.3 Darr analysis of smolt data stratified by week for Pine Gulch, 2006.

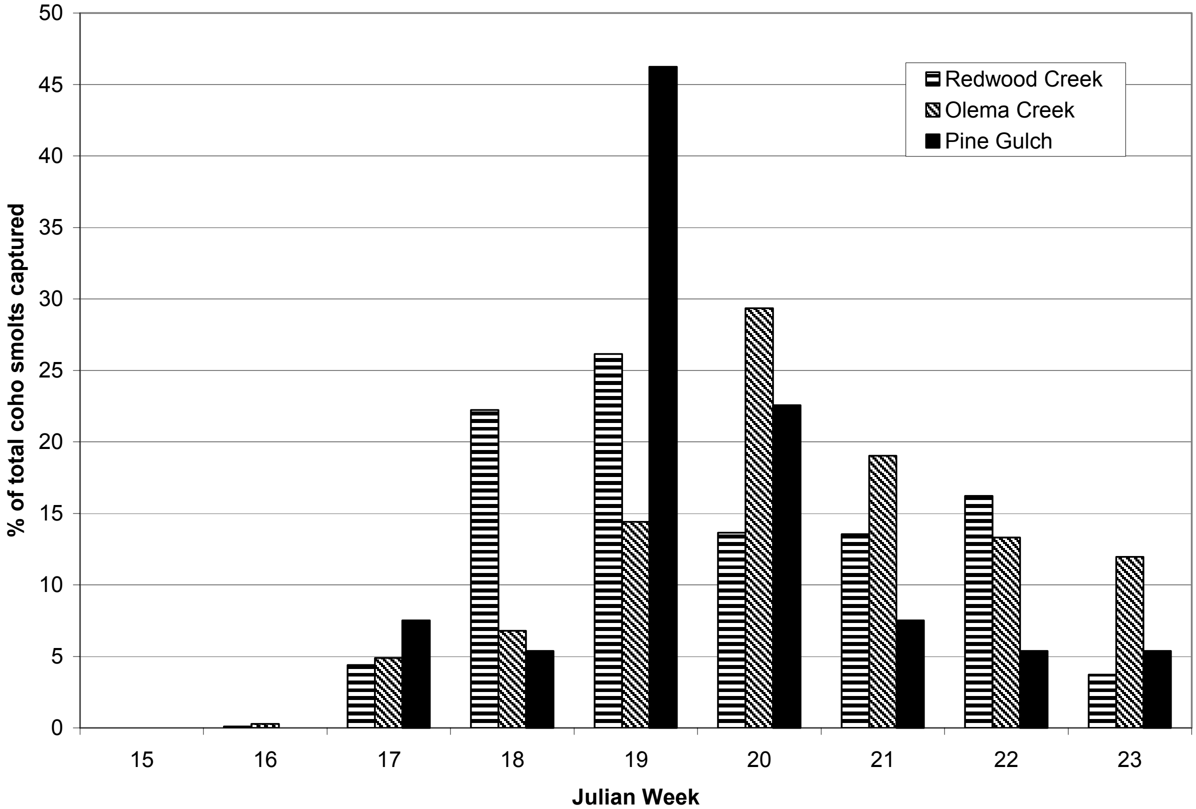


Figure 3.4 Percent of total coho smolts captured by julian week for Redwood, Olema, and Pine Gulch Creeks, 2006.

3.4 Water Temperature

Trap box temperatures fell within the tolerable temperature range (< 22ºC) for coho salmon (Moyle 2002) during the entire trapping season at all three trapping locations (Figures 3.5, 3.6, and 3.7). The highest average and maximum temperature recorded was in Olema Creek with an average temperature of 14.8 ºC (2.1 SD) and a maximum temperature of 18.2 ºC. The lowest average and minimum temperature was recorded on Redwood Creek with an average temperature of 13.2 ºC (1.4 SD) and a minimum temperature of 10.3 ºC.

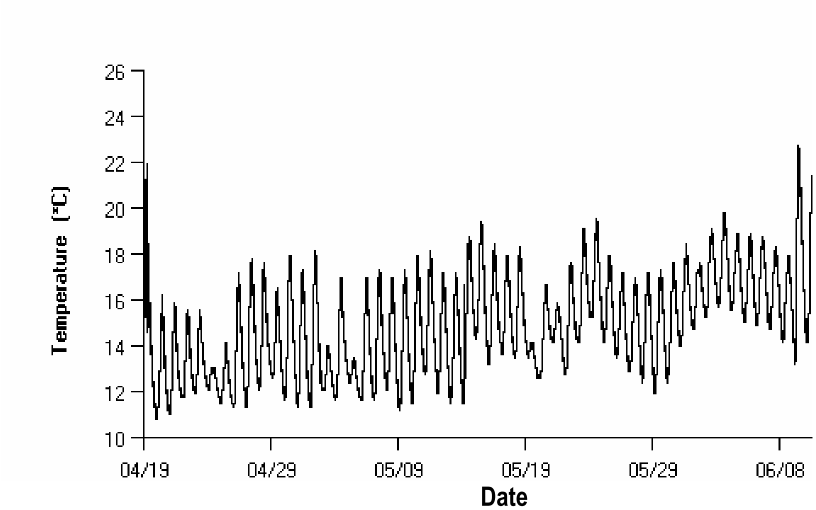


Figure 3.5 Olema Creek trap box Hobo temperature logger readout, spring 2006. Trap was pulled on June 9, 2006.

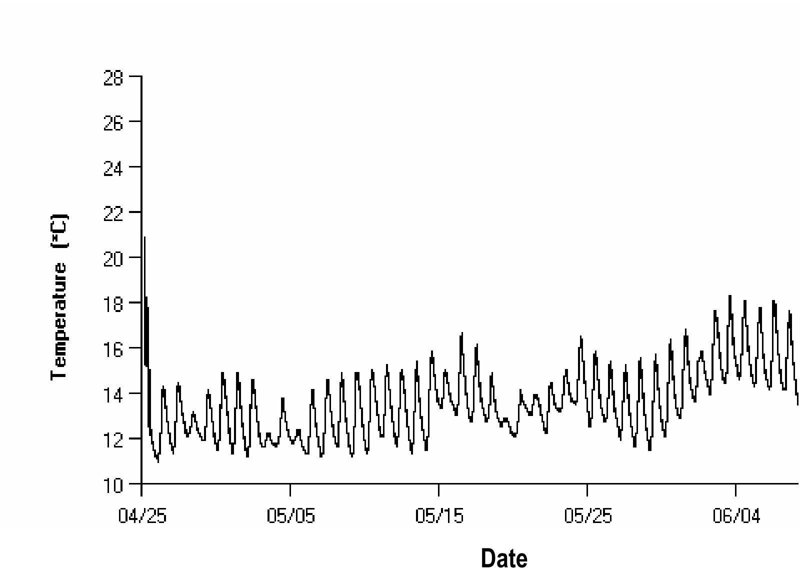


Figure 3.6 Pine Gulch trap box Hobo temperature logger readout, spring 2006. Trap was pulled on June 9, 2006.

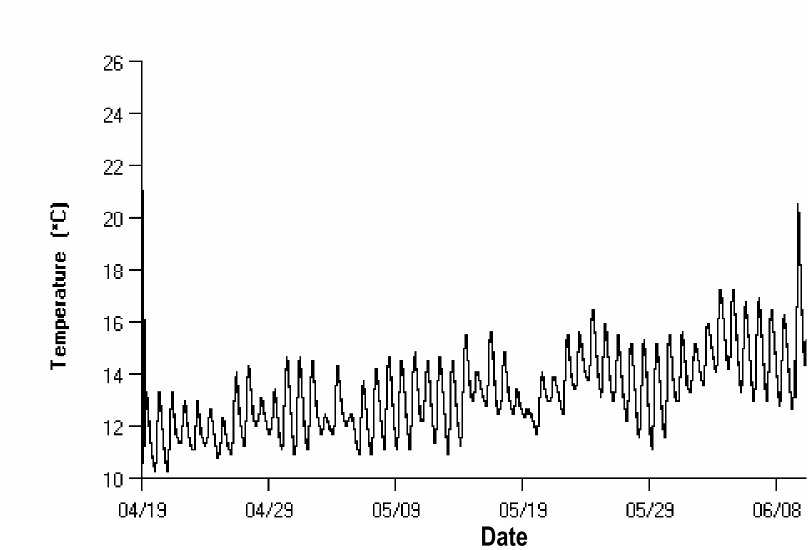


Figure 3.7 Redwood Creek trap box Hobo temperature logger readout, spring 2006. Trap was pulled on June 9, 2006.

4.0 Analysis

4.1 Population Size and Timing

In all years trapping operations were conducted within an eleven week time frame starting in late March and ending in early June. Actual start and ending dates for each year vary depending on instream flows, stream temperature, and coho smolt captures. Based on flow and capture data in last five years on Pine Gulch Creek (Figure 4.1), outmigration appears to be earlier in years when flow remained low or consistent during the beginning of the trapping period. Peak coho smolt outmigration was observed later in the trapping period in years when flows were high during the beginning of the trapping period. This suggests that coho will wait until after high flow events to continue their outmigration to the ocean.

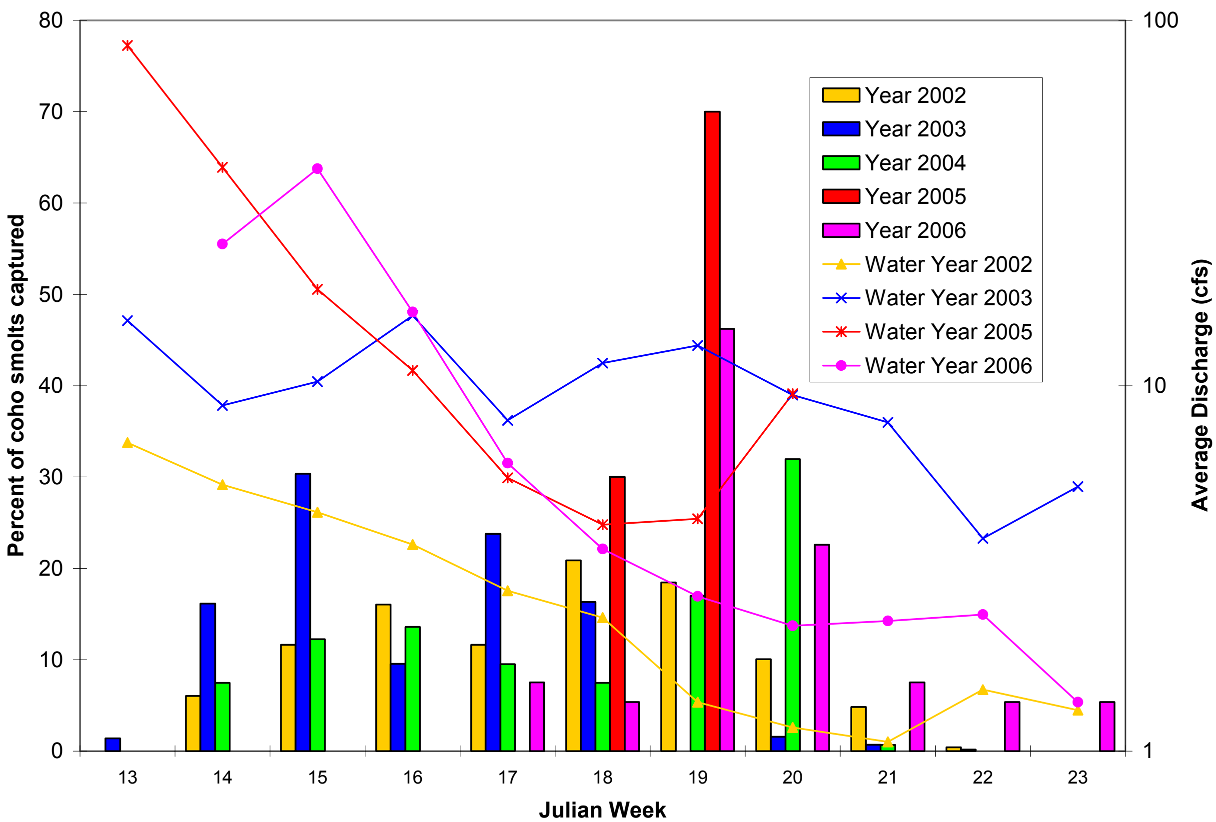


Figure 4.1 Percent of coho captured per Julian week for Pine Gulch Creek, 2002 -2006.

Coho smolt capture totals were higher in both Olema and Redwood Creeks than in previous years of trapping. In Pine Gulch only 93 coho smolts were captured with a production estimate of 368 (± 76) compared to 576 smolts captured in 2003. Steelhead and salmonid fry totals are variable from year to year with the majority of the steelhead fry being captured on Olema Creek (Table 4.1). Olema Creek had the highest calculated production estimate with a estimated 10,544 coho smolts produced in the watershed. However, it should be noted that the standard deviation of 8,399 is high for this estimate and therefore the production estimate holds little value for making inferences on the population. Although both Pine Gulch and Redwood Creek had much smaller production estimates, 368 and 3,253 respectively, they both have a much lower standard deviation which increases the utility of these estimates.

Table 4.1 Summary of salmonid information for Olema, Redwood, and Pine Gulch Creeks trap operations, 1999-2006.

Watershed	Year	Trap Operation Dates		Steelhead					Coho		Coho Production Estimate	
				Juvenile			Adult					
		From	To	smolt	parr	fry	resident	ocean-run	smolt	fry	Estimate	SD
Olema Creek	2004	30-Mar	28-May	13	5	140	0	0	229	32	831	± 167
	2005*	1-Apr	9-May	9	8	1218	0	1	87	14	1,296	± 724
	2006	10-Apr	9-Jun	6	19	497	0	0	368	51	10,544	± 8,399
Redwood Creek	2005	27-Mar	31-May	1	1	344	0	0	301	535	2,481	± 616
	2006	18-Apr	9-Jun	18	0	24	0	0	1048	27	3,253	± 542
Pine Gulch	1999	16-Apr	24-May	62	42	65	1	0	0	0	N/A	N/A
	2002	28-Mar	29-May	27	27	240	0	5	249	0	N/A	N/A
	2003	28-Mar	30-May	282	120	235	1	1	576	1	N/A	N/A
	2004	25-Mar	28-May	49	50	57	0	0	149	0	737	± 144
	2005	31-Mar	31-May	28	10	200	0	0	8	0	N/A	N/A
	2006	26-Apr	9-Jun	11	7	2	0	0	93	1	368	± 76

Coho and steelhead presmolts are included in the coho smolt totals.
* Trapping discontinued May 9 due to high flows. Trap was not reinstalled.

Annual summaries of total catch for non-salmonid species are represented in Table 4.2. Olema Creek, as well as, Pine Gulch had increases in total catch numbers while Redwood Creek had significantly less total species for 2006. No non-native species were trapped in both Olema and Redwood Creeks while Pine Gulch had only two non-native species (green sunfish) captured representing less than 1% of the total catch.

Table 4.2 Summary of non-salmonid information for Olema, Redwood, and Pine Gulch Creek trap operations, 1999-2006

Watershed	Year	Trap Dates From	Trap Dates To	CH	GSF*	GSH*	LAM	PL	RO	SCU	STK	SUC	Totals
Olema Creek	2004	30-Mar	28-May	2	1	1	15	0	274	243	3083	144	3763
	2005	1-Apr	9-May	0	0	0	33	0	1006	117	648	58	1862
	2006	10-Apr	9-Jun	0	0	0	5	1	420	644	2998	3	4071
Redwood Creek	2005	27-Mar	31-May	0	0	0	0	0	0	24	5343	0	5367
	2006	18-Apr	9-Jun	0	0	0	0	0	0	133	117	0	250
Pine Gulch	1999	16-Apr	24-May	0	0	0	5	0	18	43	4	52	122
	2002	28-Mar	29-May	0	15	0	2	0	11	94	6	0	128
	2003	28-Mar	30-May	0	10	0	4	0	0	99	9	1	123
	2004	25-Mar	28-May	0	1	0	2	0	0	101	47	0	151
	2005	31-Mar	31-May	0	22	0	7	0	1	83	43	0	156
	2006	26-Apr	9-Jun	0	2	0	2	0	0	149	9	0	162

Species Code: CH = Chinook Salmon, GSF = Green Sunfish (non-native), GSH = Golden Shiner (non-native), LAM = Lamprey spp., PL = Pacific Lamprey, RO = California Roach, SCU = Sculpin spp., STK = Threespine Stickleback, SUC = Sacramento Sucker.

4.2 Smolt Size and Condition

A variety of research has shown that ocean survival of smolts is dependent on fish size as they enter the ocean (Miller and Sadro 2003). Within intermittent stream systems such as upper Olema Creek, Pine Gulch, and Redwood Creek, fish tend to grow in the spring and early summer when feeding conditions are best. In the summer, as surface flow recedes, isolated and intermittent pools form. Within these isolated pools, water temperatures increase and the food supply decreases dramatically. Temperature and dissolved oxygen stratification in these pools often occurs, with cool water and adequate DO near the bottom. Although pools become isolated between June and October, from our observations, they still support salmonid species (both coho and steelhead). Feeding rates are reduced during these low flow summer months and the salmonids must quickly catch up in the late fall, prior to major winter storms, and during the spring, before outmigrating to the ocean. It is clear that these fish have the capacity to "catch up" as shown in growth patterns of the fish. Access to floodplain habitat during the winter and early spring is also important to support growth of salmonids prior to smoltification.

Length and weight data provide critical information that contributes to the understanding of fish heath, survival, and condition factors. In addition, length and weight data allow for estimating fork length frequency, growth rates, and biomass production. Throughout the 2006 smolt trap operations, staff recorded fork lengths (FL) and weights of a subsample of fish caught in the trap. Histograms of salmonid fork length frequencies are presented for Olema Creek coho (Figure 4.2) and steelhead (Figure 4.3); Redwood Creek coho (Figure 4.4) and steelhead (Figure 4.5); and Pine Gulch coho (Figure 4.6) and steelhead (Figure 4.7).

The coho smolt fork lengths recorded throughout the spring monitoring efforts on Olema Creek ranged from 19 to 143 mm FL. Smolt fork lengths on Redwood Creek ranged from 26mm to 135mm. On Pine Gulch smolt fork lengths ranged from 27mm to 117mm. In Olema Creek, the highest frequency of fork lengths for coho smolts occurred between 96mm to 100mm representing 23% of the subsample of coho. In Redwood Creek, the peak fork length frequency of coho smolts ranged from 90mm to 100mm representing 47%. In Pine Gulch, the greatest frequency of fork lengths of coho smolts ranged from 106mm to 110mm representing 32%.

Comparisons can be made of coho condition factors of coastal drainages in the surrounding area during the 2006 smolt trap operations. Figure 4.8 represents the fork length frequency of coho smolts trapped in the San Geronimo Creek. Figure 4.9 depicts the fork length frequencies of coho smolts trapped in the Upper Lagunitas Creek while Figure 4.10 represents coho smolts trapped within the Lower Lagunitas Creek.

Coho smolt fork lengths on San Geronimo ranged from 55mm to 149 mm with the highest frequency of fork lengths occurring between 106mm to 110mm representing 24% of the measured subsample. In the Upper Lagunitas Creek, the highest fork length frequency for coho smolts ranged from 106mm to 110mm representing 21% of the measured sample. In the Lower Lagunitas Creek 20% of the smolts represented the peak fork length frequency of 116mm to 120mm.

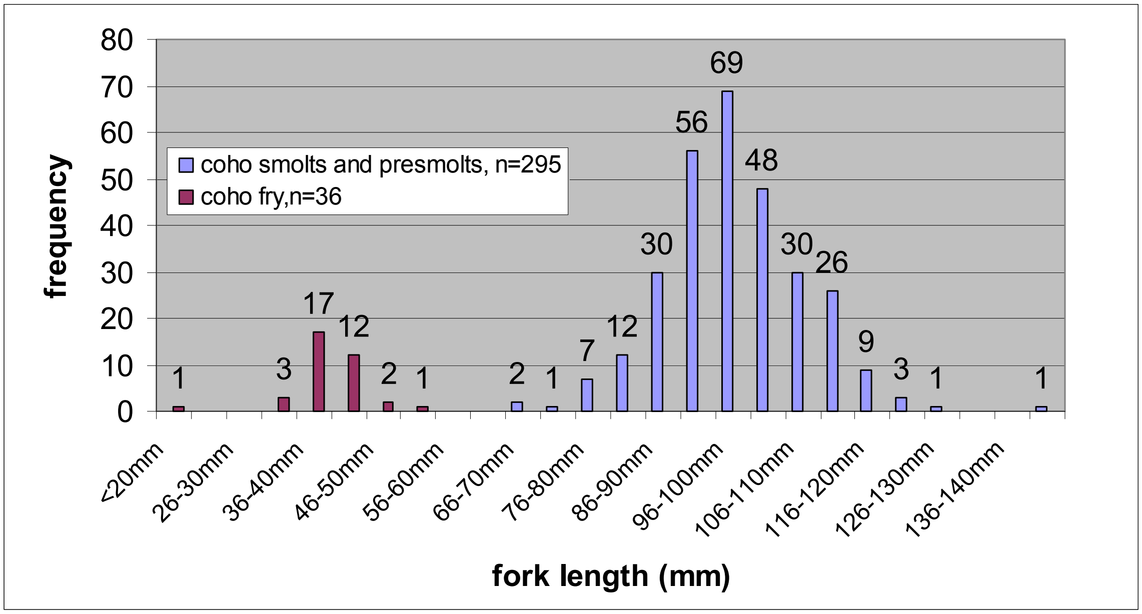


Figure 4.2 Coho smolt and fry fork lengths in 10 mm increments for Olema Creek, 2006.

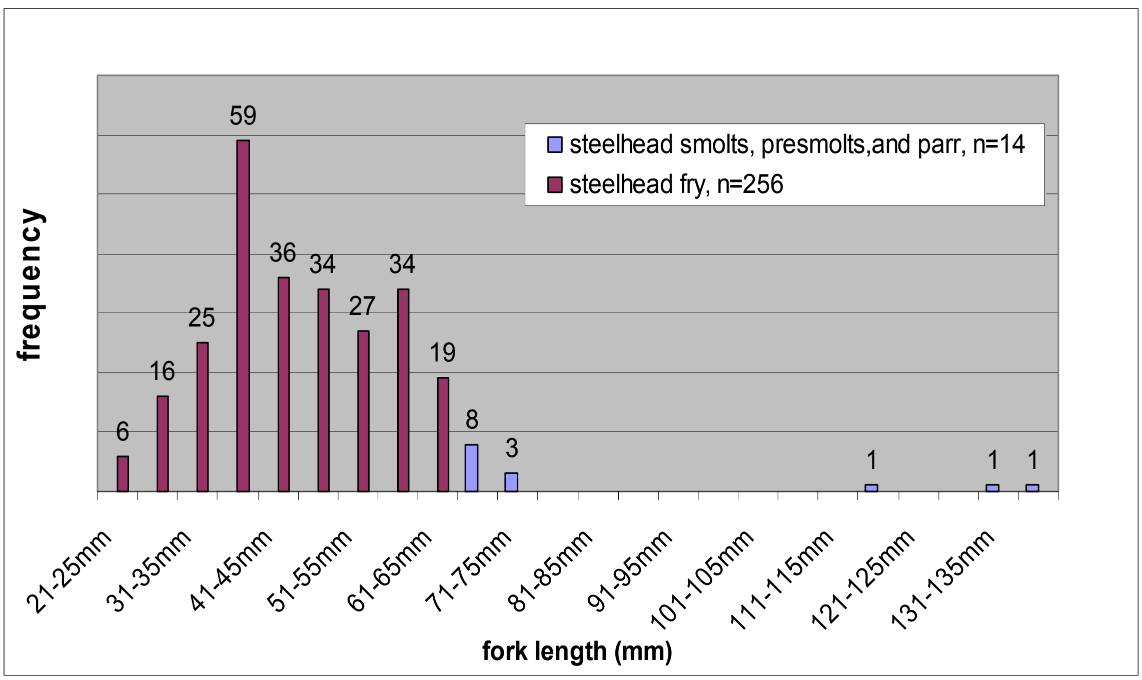


Figure 4.3 Steelhead smolt and fry fork lengths in 5 mm increments for Olema Creek, 2006.

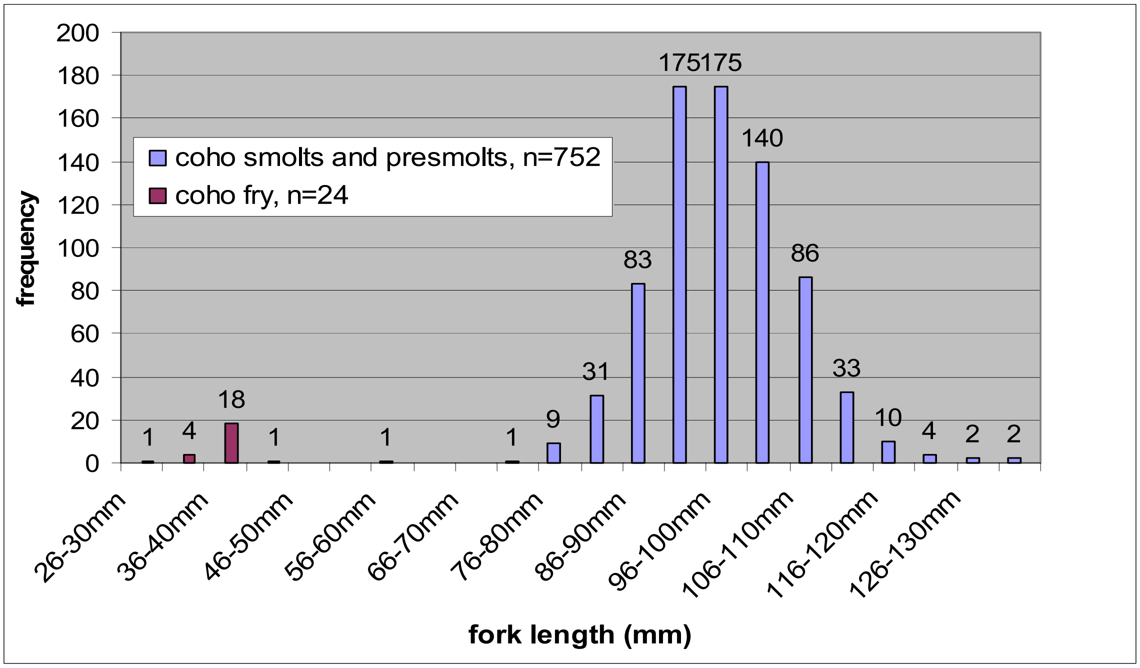


Figure 4.4 Coho smolt and fry fork lengths in 5 mm increments for Redwood Creek, 2006.

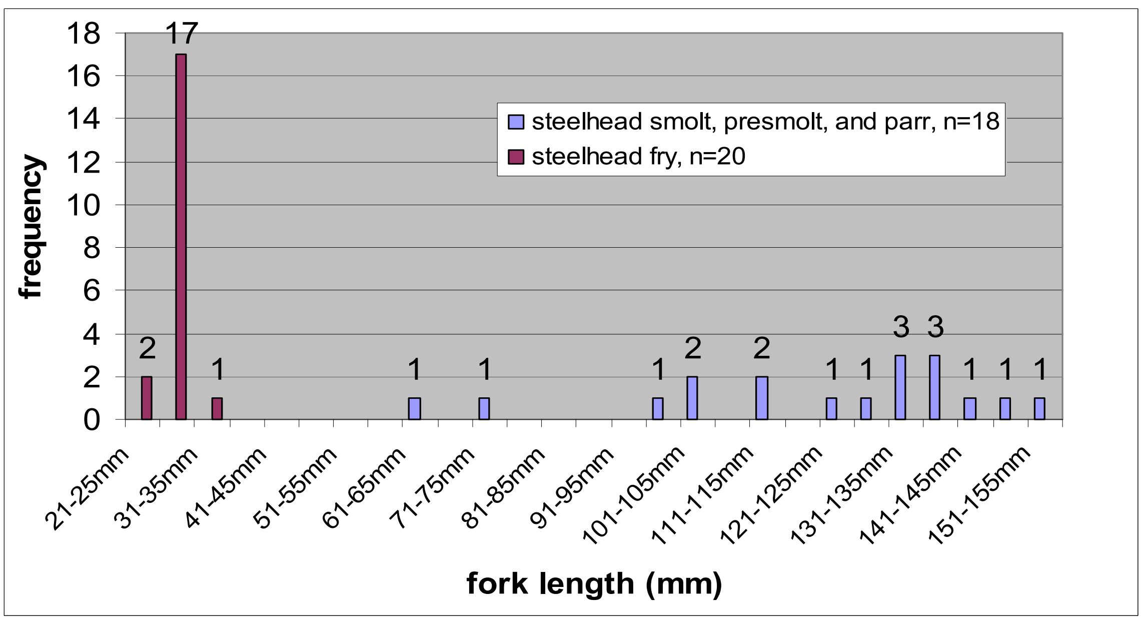


Figure 4.5 Steelhead smolt and fry fork lengths in 5 mm increments for Redwood Creek, 2006.

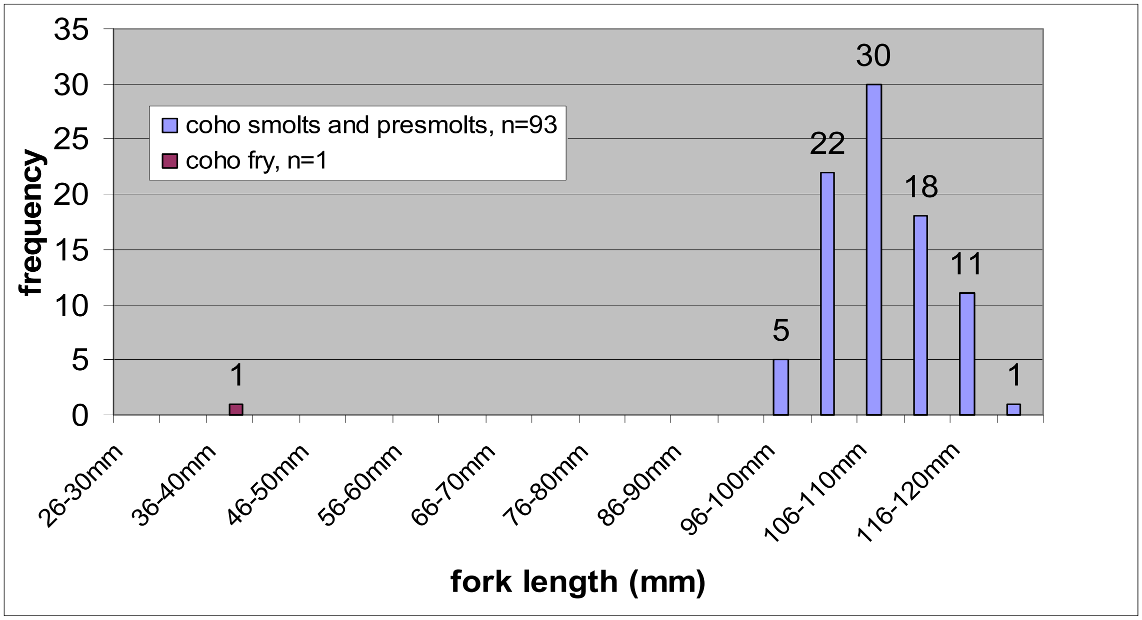


Figure 4.6 Coho smolt and fry fork lengths in 5 mm increments for Pine Gulch Creek, 2006.

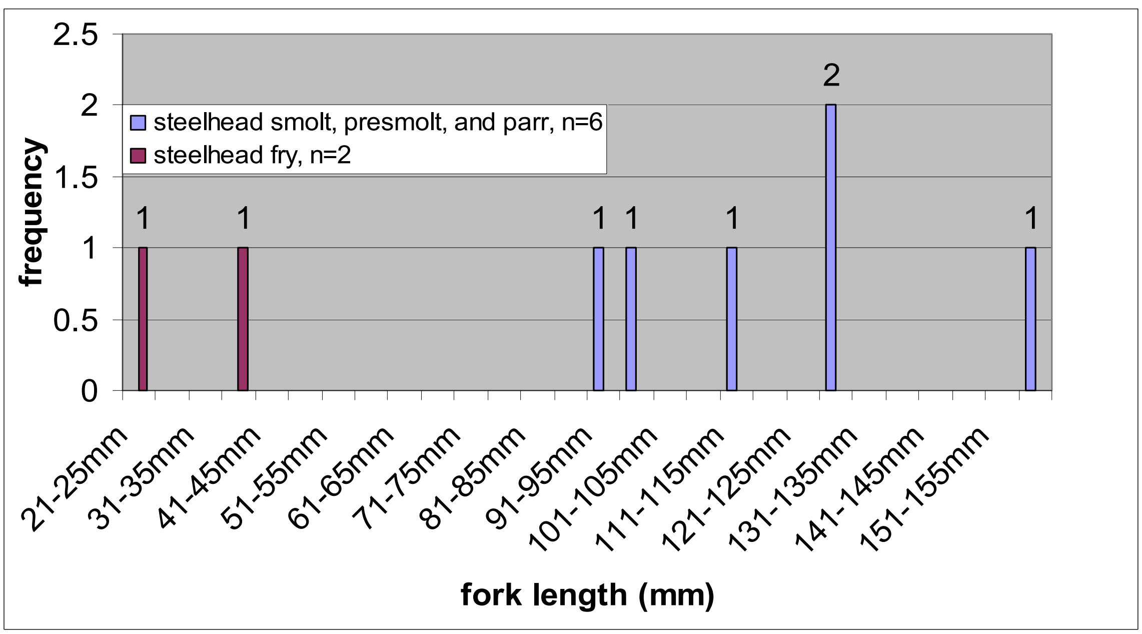


Figure 4.7 Steelhead smolt and fry fork lengths in 5 mm increments for Pine Gulch Creek, 2006.

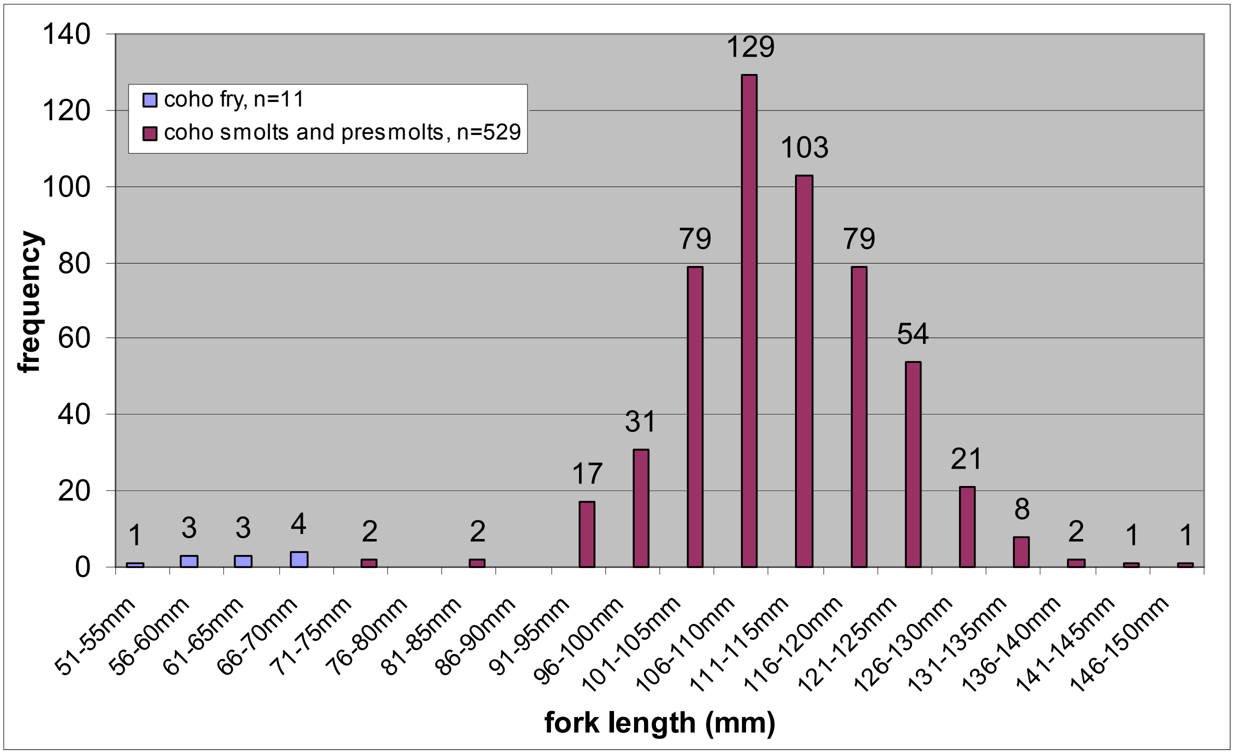


Figure 4.8 Coho smolts and fry fork lengths in 5 mm increments for San Geronimo Creek, 2006.

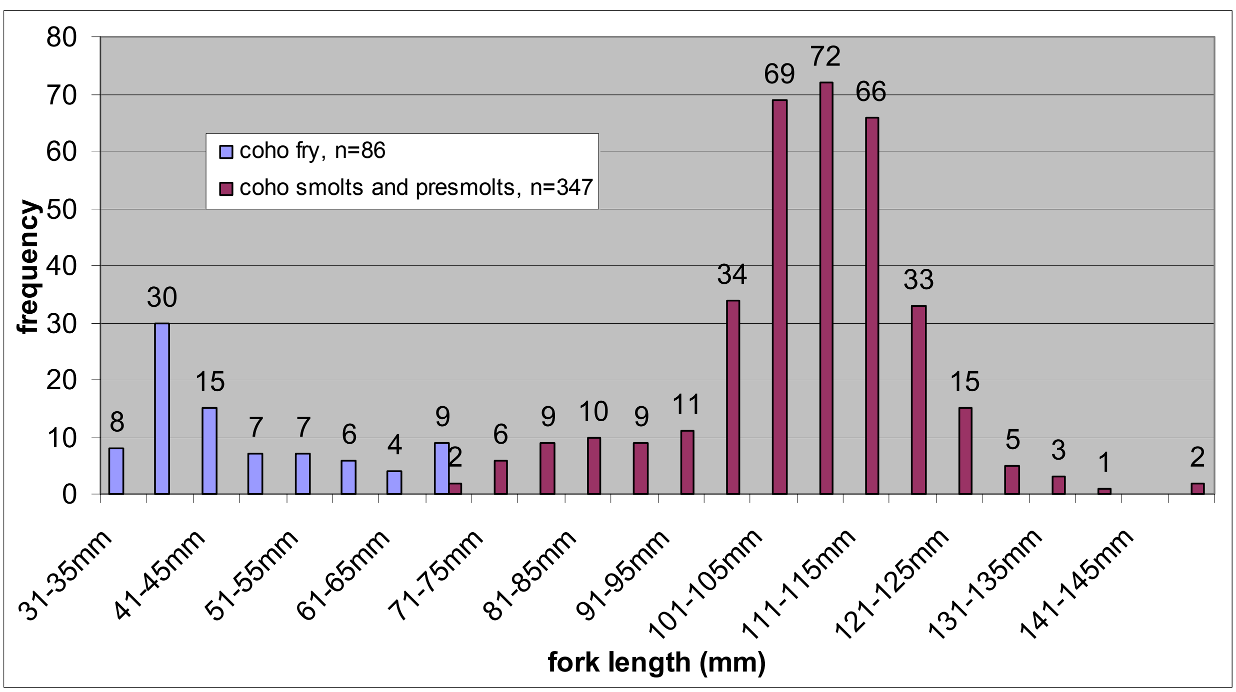


Figure 4.9 Coho smolts and fry fork lengths in 5 mm increments for Upper Lagunitas Creek, 2006.

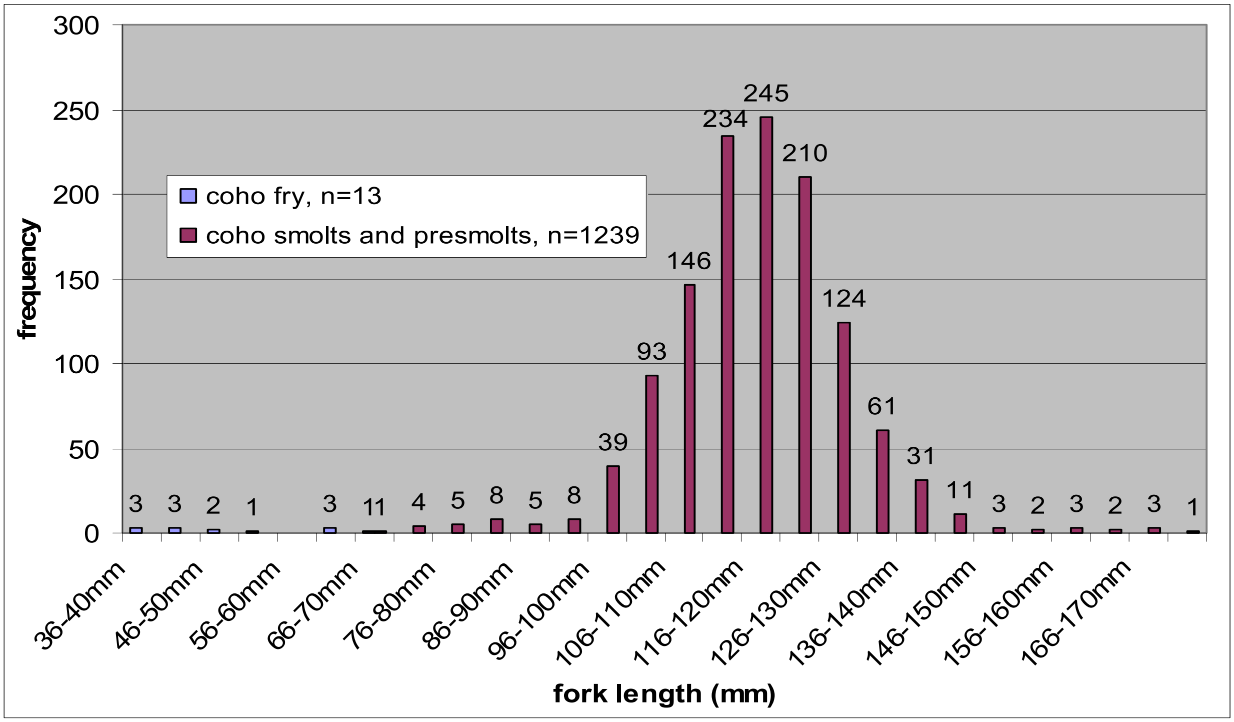


Figure 4.10 Coho smolts and fry fork lengths in 5 mm increments for Lower Lagunitas Creek, 2006.

In addition, comparisons can be made between all three monitoring sites of coho salmon weight-length relationships shown here in Figure 4.11.

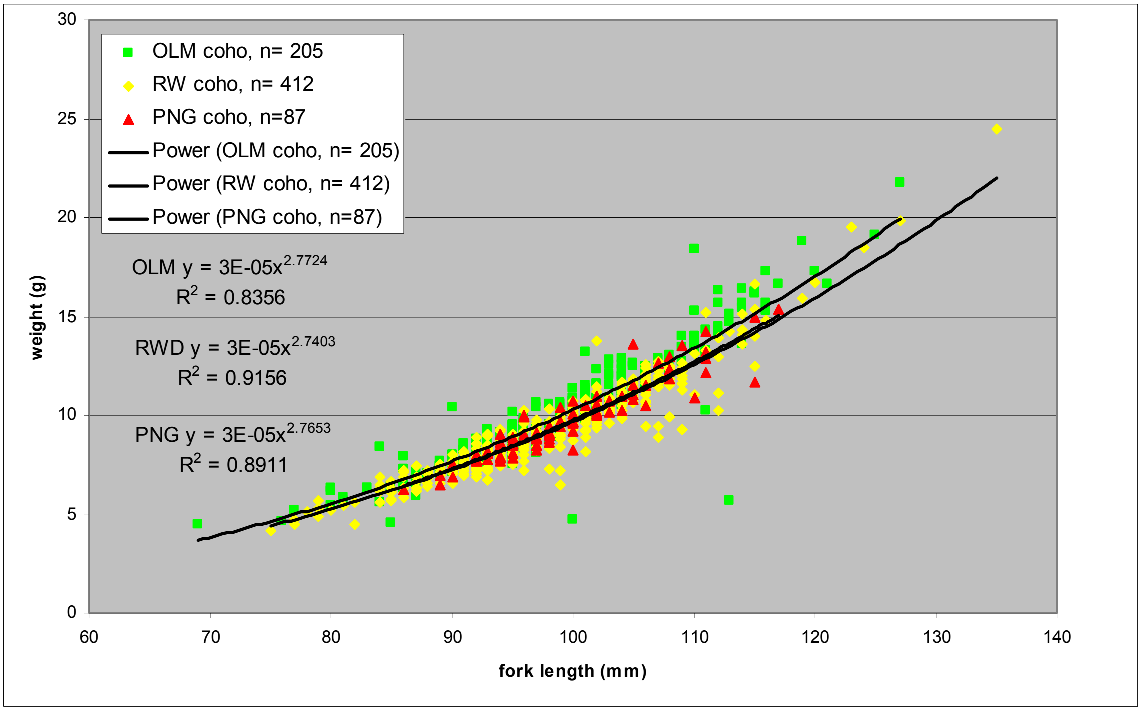


Figure 4.11 Weight-Length comparison between 1+coho of Olema, Redwood, and Pine Gulch Creeks for 2006.

Length is the principal factor affecting the weight of fishes. In spite of this, there can be significant differences in weight distribution between similar size fish of the same species within a particular watershed and within the surrounding region. In order to compare length-weight relationships, we applied the Fulton Condition Factors (K) to establish comparable indices of condition. Condition factors are a ratio relating fish length to fish weight therefore measuring the relative biomass of a fish. Table 4.3 shows the comparisons between coho smolt length and K-factors of six different monitoring sites.

The average coho smolt fork length of fish sampled at Olema, Redwood, and Pine Gulch creeks ranged from 97.65mm in Redwood Creek to 99.63mm in Pine Gulch. The mean weight of coho ranged from 9.25g in Redwood Creek to 10.22g in Olema Creek with the mean K-factor equal in both Redwood Creek and Pine Gulch at 0.98 and a higher mean K-factor of 1.04 in Olema Creek.

The average coho smolt fork length of fish sampled at San Geronimo, Upper, and Lower Lagunitas creeks ranged from 98.32mm in the Upper Lagunitas Creek to 115.29mm in the Lower Lagunitas Creek. The mean weight of smolts ranged from 11.67g to 17.14g in the Upper and Lower Lagunitas Creek respectively. The mean K-factor ranged from 1.01 in the Lower Lagunitas Creek to 1.08 in the Upper Lagunitas Creek.

Table 4.3 Mean Length, Weight, and K factor calculated for the six trapping locations in West Marin County, 2006.

Watershed	Year	Species	Sample Size	Mean Length (mm)	Length Standard Deviation	Mean Weight (g)	Weight Standard Deviation	Mean K-Factor	K-Factor Standard Deviation
Olema Creek	2006	Coho	205	98.73	9.59	10.22	3.08	**1.04**	0.11
Redwood Creek	2006	Coho	412	97.65	8.42	9.25	2.41	**0.98**	0.07
Pine Gulch	2006	Coho	87	99.63	6.44	9.78	1.89	**0.98**	0.06
San Geronimo Creek	2006	Coho	380	109.39	12.03	14.39	4.07	**1.07**	0.10
Upper Lagunitas Creek	2006	Coho	315	98.32	22.34	11.67	6.01	**1.08**	0.12
Lower Lagunitas Creek	2006	Coho	589	115.29	15.83	17.14	6.53	**1.01**	0.09

4.3 Multiple Life Stage Comparisons

Based on basinwide habitat surveys conducted during the summer of 2005, Redwood, Olema, and Pine Gulch Creeks contain comparable habitat composition. Through multiple life stage monitoring, the NPS is able to develop survival estimates for each stage of the coho life history. While we are able to derive an extrapolated survival rate estimate using this method, we still do not have a means of developing a confidence interval at this time. Survival rates are still provided as a comparison between watersheds and life stages. For the 2004-05 spawner year, the highest survival rate for all life stages was observed in Pine Gulch with an egg to smolt survival rate of 5.6% (Table 4.4). The high survival rates in Pine Gulch may be explained by the decrease in interspecies competition during the summer rearing period since the population is still relatively small in this watershed. Overwintering survival rates in Pine Gulch are comparable to those observed in the nearby Russian River coho enhancement project which uses hatchery reared coho juveniles to supplement a struggling native stock (Obedzinski pers comm.). The lowest survival rate for all life stages was observed in Redwood Creek with an egg to smolt survival rate of only 1.5% (Table 4.4). Based on summer juvenile basinwide estimates, the largest source of mortality in Redwood Creek occurred during the egg to juvenile life stage. The overwintering survival rate in Redwood Creek is comparable to both Olema and Pine Gulch Creeks which indicates adequate overwintering habitat.

Table 4.4. A Comparison of Multiple life stage observations of coho salmon within the Redwood Creek watershed, Olema Creek mainstem, and Pine Gulch mainstem for the 2004-05 Year Class.

	Spawner Year 2004-05		
	Redwood Creek	**Olema Creek**	**Pine Gulch Creek**
PLD Index	171	184	3
Redds	93	98	3
Average Female Fork Length	63.3	65.7	62.5[a]
Estimated number of Eggs	212,315[b]	249,599[b]	6,597[b]
Basinwide Juvenile Estimate[c]	8,953 ± 1,771	27,943 ± 8,057	1,150 ± 554
Estimated Survival Rate Egg to Juvenile	4.2%	11.1%	17.4%
Watershed Smolt Production Estimate[d]	3,253 ± 542	10,544 ± 8,399	368 ± 76
Estimated Survival Rate Juvenile to Smolt	36.3%	37.7%	32.0%
Estimated Survival Rate Egg to Smolt	1.5%	4.2%	5.6%

[a] Average female length based on female carcass lengths on Redwood Creek for spawner years 1997-98 thru 2004-05.

[b] Estimated number of eggs using Shapovalov and Taft (1954) formula based on average female fork length

[c] Collected during summer 2005 NPS basinwide surveys .

[d] This report.

5.0 RECOMMENDATIONS

5.1 Trapping Location

Although downstream migrant traps were installed later than usual due to high flows, most of the trapping techniques used were effective at meeting our monitoring objectives. However, the Olema Creek trapping location has proven to be inefficient in the last three years of trapping operations. For this reason this trap should be moved to a new location for future proposed trapping operations. A new location will hopefully provide better access and higher trapping efficiencies then the current location. If necessary a rotary screw trap may be installed during above average water years to increase trapping efficiency.

5.2 Mark Retention

A mark retention study should be performed using hatchery fish before each season in order to evaluate the utility of the panjet marking technique. Smolt production estimates rely on the retention of marks on marked fish for the duration of the study period. Un-retained marks will cause an inflation in the smolt production estimate resulting in an increased survival rate estimate.

5.3 Trapping effectiveness

A fyke/pipe style trap should be used instead of the pipe style trap currently used at Pine Gulch. Pipe style traps are limited in their ability to transport water through the trap and thus becoming insufficient during moderate to high flow conditions. Since it is not required to impound water in a fyke/pipe style trap, fyke/pipe traps will increase capture efficiencies during moderate to high flow events.

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